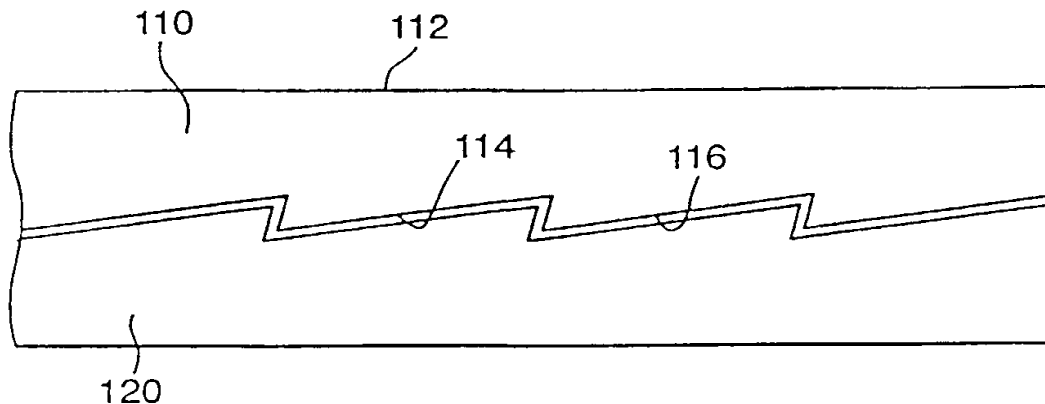


INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁷ : G03B 21/62, G02B 3/08		A1	(11) International Publication Number: WO 00/70404
			(43) International Publication Date: 23 November 2000 (23.11.00)
(21) International Application Number: PCT/GB00/01858 (22) International Filing Date: 15 May 2000 (15.05.00) (30) Priority Data: 9911306.0 14 May 1999 (14.05.99) GB (71) Applicant (<i>for all designated States except US</i>): MICROSHARP CORPORATION LIMITED [GB/GB]; 52 Shrivenham Hundred Business Park, Watchfield, Swindon, Wiltshire SN6 8TY (GB). (72) Inventors; and (75) Inventors/Applicants (<i>for US only</i>): FAIRHURST, Alison, Mary [GB/GB]; 83 Cromwell Avenue, Thame, Oxfordshire OX9 3YE (GB). CLABBURN, Robin, James, Thomas [GB/GB]; Buckthorn House, Sevenhampton, Wiltshire SN6 7QA (GB). (74) Agent: HOWDEN, Christopher, A.; Forrester Ketley & Co., Forrester House, 52 Bounds Green Road, London N11 2EY (GB).		(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG). Published <i>With international search report.</i>	

(54) Title: DISPLAY AND LIGHT-TRANSMITTING PLATE FOR A DISPLAY



(57) Abstract

A semi-reflecting plate for use with a liquid crystal display, for example, comprises a first body (110) of light-transmitting material having a flat upper surface and a stepped lower surface carrying a semi-reflective coating (116) and a second body (120) of light-transmitting material, underneath the semi-reflective coating, the second body (120) of light-transmitting material being in intimate contact with the coated stepped surface of the first body (110) and thus being correspondingly stepped, the second body (120) having a flat lower surface parallel with the flat upper surface of the first body. In a preferred arrangement, the refractive index of the second body is equal to, or close to that of the first body, so that light passing straight through the plate suffers little or no refractive deviation, whilst light reflected from the semi-reflective coating undergoes a predetermined angular deviation. In variants, the bodies (110, 120) may have different refractive indices and/or the semi-reflective coating may be omitted.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece	ML	Mali	TR	Turkey
BG	Bulgaria	HU	Hungary	MN	Mongolia	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MR	Mauritania	UA	Ukraine
BR	Brazil	IL	Israel	MW	Malawi	UG	Uganda
BY	Belarus	IS	Iceland	MX	Mexico	US	United States of America
CA	Canada	IT	Italy	NE	Niger	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NL	Netherlands	VN	Viet Nam
CG	Congo	KE	Kenya	NO	Norway	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NZ	New Zealand	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	PL	Poland		
CM	Cameroon	KR	Republic of Korea	PT	Portugal		
CN	China	KZ	Kazakstan	RO	Romania		
CU	Cuba	LC	Saint Lucia	RU	Russian Federation		
CZ	Czech Republic	LI	Liechtenstein	SD	Sudan		
DE	Germany	LK	Sri Lanka	SE	Sweden		
DK	Denmark	LR	Liberia	SG	Singapore		
EE	Estonia						

Title: "Display and Light-Transmitting Plate for a Display"

THIS INVENTION relates to a light diffusing sheet material having utility in various fields, including that of enhancing video displays, such as LCD displays.

In liquid crystal displays the bright image seen by the viewer is generated through the liquid cell either by light generated within the assembly by a back light or by the use of ambient light which is first transmitted through the cell and reflected at the rear of the cell, re-emerging through the cell to create a bright image. In this latter arrangement, due to the position of the viewer, the majority of light must be accepted off axis, preferably should not be further diffused on entering the display, and should preferably re-emerge on axis with some additional diffusion in order to provide an acceptable viewing cone. It is well known that Fresnel-like structures have the ability to re-direct light; as circular arrangements of facets to create lenses, or as linear arrangements of facets to create off axis effects. Structures of these types have been proposed incorporating materials with light diffusing characteristics, as described in US Patent No. 4911529, where the diffusive effect is provided by a so-called bulk diffuser comprising small particles of a material of a first refractive index dispersed in a matrix material of a second refractive index. Such materials are described in, for example US Patent No. 4983016, EP-A-0464499 or EP-A-0843203. An important characteristic of such bulk diffuser materials is that the amount of diffusion taking place within a given composition is dependant on the thickness of material through which the light travels. As a result, light entering an assembly containing such material off axis becomes more diffuse and reduced in intensity than light which enters on axis.

According to one aspect of the present invention there is provided an optical device comprising an element of light-transmitting material having a surface thereof configured to form a stepped, Fresnel-type light refracting element, such light transmitting material incorporating an array of integral graded refractive index structures adapted to impart light dispersing or diffusing characteristics to said light-transmitting sheet material or the element having a layer configured to form said stepped surface and an additional layer incorporating such an array of integral graded refractive index structures.

The applicants have found that, with a device of this character, light entering the device off-axis is diffused less and is less reduced in intensity than light entering on axis.

In certain instances, it may be desirable to render one surface of said element reflecting or partially reflecting by coating with a material with the necessary optical properties, such as a metal applied by deposition or sputtering.

The sheet material may comprise, for example, a photopolymer, in which the graded refractive index features are formed by exposure of a precursor of the material, (such as a monomer) to appropriate radiation in a predetermined pattern so as to produce localised variations of light intensity within the material and hence localised variations in degree of polymerisation and thus in refractive index. As another example, the material may be dichromated gelatine (DCG), in which the desired graded refractive index features are formed by exposure of the material itself to such a radiation pattern, to produce an equivalent effect. Such materials, correctly processed, possess the previously described desirable optical characteristics. The process techniques used may, for example include, those disclosed in EP-0294122 or EP-0801767 or US Patent No. 5695895 or GB-A-1499135. These types of diffusing materials may

themselves have off axis or asymmetric characteristics, as described in EP 0768565, which can further enhance the off axis effects generated by the Fresnel structure. Methods of producing sheets of light diffusing material in which the light-diffusing characteristics are due to refractive index variations within the material are known and will not be discussed in greater detail here. These known methods, however, are directed to the production of either planar light-diffusing sheets or light-diffusing sheets having a surface configuration in the form of a plurality of convex domes, for example, adapted to enhance the diffusive characteristics of the material.

According to another aspect of the invention, there is provided an LCD display, incorporating a light-transmitting element having a surface with surface relief or texturing to eliminate or reduce reflections.

According to another aspect of the invention there is provided a sheet of light-transmitting material which sheet has one surface stepped or ramped to act as a Fresnel refractor or reflector and has an opposite surface which has surface relief or texturing to reduce reflection of light from that other surface.

In further aspects of the invention, there is provided an optical plate or sheet comprising a first body of light-transmitting material having an outer surface and an inner stepped or ramped surface carrying or conforming with and/or adhered to a second body of light-transmitting material, said second body of light-transmitting material having an outer surface remote from said coating and an inner surface conforming with and/or adhered to said stepped or ramped surface of said first body. Such a plate or sheet thus presents generally flat parallel surfaces on opposite sides thereof, which facilitates incorporation of the product into a stack with other flat sheets or plates, such as liquid crystal

cells, polarising sheets, etc. in manufacture of products utilising such an optical sheet or plate.

Thus, according to one such further aspect, there is provided a light-transmitting plate or sheet comprising a first body of light-transmitting material having an outer surface and an inner stepped or ramped surface carrying or conforming with and/or adhered to a second body of light-transmitting material, said second body of light-transmitting material having an outer surface remote from said coating and an inner surface conforming with and/or adhered to said stepped or ramped surface of said first body, the refractive index of said second body of light-transmitting material being different from that of said first body of light-transmitting material, whereby light is refracted in passing from said first to said second body of light-transmitting material.

According to another such further aspect of the invention there is provided a partially light-reflecting, partially light-transmitting plate comprising a first body of light-transmitting material having an outer surface and an inner stepped or ramped surface carrying or conforming and/or adhered to with a semi-reflective coating and a second body of light-transmitting material, on the opposite side of said semi-reflective coating from said first body of material, said other side of said coating being correspondingly stepped or ramped, said second body of light-transmitting material having an outer surface remote from said coating and an inner surface conforming with and/or adhered to said opposite side of said semi-reflective coating, the refractive index of said second body of light-transmitting material being equal or close to that of said first body of light-transmitting material, whereby light suffers little or no refraction in passing from said first to said second body of light transmitting material.

Embodiments of the invention are described below with reference to the accompanying drawings, in which:-

FIGURE 1 is a view, in section perpendicular to the plane of major extension of the material, of a first embodiment of the invention,

FIGURES 1a and 1b are corresponding views of variants each having a reflective coating,

FIGURE 2 is a view, partly in section and partly in perspective of another form of light-diffusing sheet in accordance with the invention,

FIGURES 2a and 3, 3a and 3b are sectional views similar to Figure 1, showing specific examples of materials in accordance with the invention,

FIGURE 4 is a graph showing diffusive characteristics for various materials,

FIGURE 5 is a view, similar to Figure 1, showing a further embodiment of the invention,

FIGURE 6 is a schematic sectional view illustrating an effect which may arise in use of the embodiment of Figure 5, and

FIGURE 7 is a schematic sectional view of a further embodiment by which the effect illustrated in Figure 6 may be avoided.

In the embodiments of the present invention shown in the drawings, the device has the general form of a sheet 13 of light diffusing material, one surface of which is provided with a stepped or grooved configuration, after the fashion of

a Fresnel lens or prism. As a result, the device, in addition to its diffusive characteristics, also has a directional characteristic in the sense that, if a parallel beam of light is directed on the sheet from one side thereof, the polar distribution of the diffused light emerging from the device has a peak along a direction which differs from the direction of the axis of the incident beam by an angle representative of the deviation imparted by the prismatic component due to the Fresnel prism surface configuration. The stepped surface of the device has, in cross-section, as shown in the Figures, a saw-tooth profile section, comprising major facets or ramps inclined typically at 10° to 20° to the general plane of the sheet, and minor facets extending generally perpendicular to said plane.

In the example shown in Figure 1, a light beam entering the material from below, normal to the (planar) lower surface is shown as passing through the material undeviated to pass through one of the facets of the Fresnel structure forming the upper surface, to be refracted through a 5° angle. In the example shown, the Fresnel structure comprises a series of major facets each inclined at 10° to the plane of the lower surface. It will, of course, be understood that these figures are merely exemplary. It will also be understood that the illustration of Figure 1 neglects the diffusive effect of the material. Taking this effect into account, it will be appreciated that the overall effect, for a parallel beam entering the material along the ray path indicated, is to produce, within the material, a spreading or scattering of light in a polar distribution with an intensity peak along the ray path shown.

Referring to Figure 1b, an arrangement is shown which is similar to that of Figure 1 except that the stepped upper surface is rendered reflective, for example by metallisation e.g. applied by vapour deposition or by sputtering. The incorporation of a reflecting surface removed from the surface through

which the light enters the assembly, causes the light, initially entering the material from below at a significant (35° - 40°) angle to the normal, to be reflected at the reflective facets, passing through the material a second time to become more diffuse before emerging substantially on axis, that is to say emerging as a dispersing "bundle" of rays in a distribution having a maximum along the normal to the planar face.

Figure 1a shows an arrangement similar to that of Figure 1b, except that the light transmitting layer provided with the Fresnel-faceted surface (and which layer is indicated at 22 in Figure 1a) is of non-diffusive, transparent material and the desired diffusive effect is provided by an additional layer, referenced 23, of light-diffusing material. In the embodiments of Figures 1a and 1b described above, in which reflecting coating is used, that coating is applied to the corrugated or faceted surface of the material, arranged as the rear surface of the screen, in order to secure a more pronounced off-axis effect. However, the reflective coating may, of course, be applied to the flat surface of the device, again arranged as the rear surface.

Figure 2 shows, partly in section and partly in perspective, a light-diffusing, light-transmissive sheet in accordance with the invention, comprising a layer 32 having a Fresnel stepped or faceted surface, and a flat substrate layer 33. The layer 32 may be of light-diffusing material and substrate 33 of transparent non-diffusive material, such as polyester or polycarbonate, or, similarly to the arrangement of Figure 1a, the layer 32 may be non-diffusive and the layer 33 diffusive.

Fig. 2a shows a specific example of an arrangement corresponding to that of Figure 2 wherein the Fresnel structure has a pitch of 50 microns and a facet angle of 10 degrees. Again, neglecting, initially, the diffusive characteristics of

the material, a light beam entering on axis (i.e. normal to the "plane" of the material), exits at 5° to the normal.

Fig. 3 shows an embodiment similar to that of Figure 1 and having, by way of example, a Fresnel structure the pitch of which is 50 microns with a facet angle of 20 degrees. Fig. 3a shows a structure of the same pitch and facet angle, and shows additionally, for illustration, different ray paths through the light diffusing material 13. Figure 3b shows a structure similar to that of Figure 2a, but in which, however, the substrate layer, referenced 43, is a layer incorporating graded refractive index features arranged to impart a net deflective effect upon light passing therethrough as well as, typically, diffusing the light passing therethrough. Thus, in the example illustrated, light entering the layer 43 normal to its exposed lower (in the figure) surface, is subjected to a net, or average deflection of 20° . The Fresnel-faceted layer referenced 42, in this case may simply be transparent and non-diffusive or may itself be light-diffusing.

The ray diagrams in Figures 1 to 3b, as noted, neglect, for ease of illustration, the fact that the light-transmitting layers of the device are not simply transparent, but that one or each such layer has a light-diffusing character.

Thus, in place of the emerging ray illustrated, there will, in practice, be a dispersing "bundle" of rays in a distribution having a maximum along the emerging ray path illustrated.

The stepped surface in the above embodiments may define, in effect, a plurality of precisely parallel similar V-section grooves extending across the sheet material so that, neglecting the diffusive features, the material acts as a thin prism. Alternatively, however, the grooves and ridges defined by the stepped

surface may extend in circles or arcs and be of a form corresponding to that of the stepped surface of a Fresnel lens, whereby the refraction or reflection at the stepped surface will tend to "focus" the diffusive light provided thereby. In addition, the presence of the diffusing material will mask the discontinuities in the Fresnel structure to the viewer.

In the preferred embodiments discussed, the light diffusing character of the light diffusing layer arises as a result of incorporating an array of graded refractive index features, for example graded refractive index microlenses or other features. These graded refractive index microlenses preferably have each a transverse dimension, i.e. a dimension measured parallel with the major planes of the sheet, which is small in relation to the pitch of the corrugated surface, i.e. the spacing between, for example, peaks of adjacent ridges of the corrugated surface, the graded refractive index features being likewise closely spaced in relation to one another, so that, for example, the mean spacing between adjacent such features may be several orders of magnitude less than the pitch of the corrugations on the surface. In the examples discussed, the graded refractive index features typically have an average diameter of 5 microns spaced apart (centre to centre), by, for example, a distance of 8 microns. Preferably in each said graded refractive index feature, the refractive index may be substantially constant along any line perpendicular to the plane of the sheet but may vary with transverse position in the sheet material. Thus, in the case of a graded refractive index lens, the refractive index may vary with radial distance from the optical axis of the lens, as described in EP-A-0294122.

The refractive index gradations in the light-diffusing material may be produced by photographic means, for example, by contact printing through an appropriate mask as described in EP-A-0294122. However, whereas in EP-A-0294122, for example, the optical mask utilised is preferably plane, for the

purposes of the present invention, the optical mask may comprise, for example, a glass plate having the desired stepped configuration on one surface and having that one surface coated with a thin layer of, for example, metallic chrome, so thin as not to alter the corrugated character of the glass surface, the chrome layer being provided with an array of transparent windows or apertures etched therein by photo-etching techniques so as to form an optical printing mask. The stepped, chromed surface of the plate may then be pressed against the exposed surface of, for example, a layer of photopolymerisable monomer (destined to form the layer 33 of Figure 2, for example) on a transparent substrate, so as to form the desired corrugations by what is effectively an embossing technique. Alternatively the photopolymerisable material may be cast on the stepped chromed surface. The layer of photopolymerisable monomer, still in contact with the glass plate or mask, may then be exposed to polymerising light through such mask. Thereafter, and after a subsequent blanket exposure to polymerising light, for example directed through the transparent substrate, the plate may be separated from the finished product. Alternatively, the diffuser/Fresnel lens or prism combination can be created a two step process; forming a planar diffuser as previously described then embossing the Fresnel structure into one surface using a combination of heat and some pressure. In this instance the embossing may be effected using a copper die, formed by machining the Fresnel structure into the surface of a copper plate using a diamond tool. Whilst the above description, and EP-A-0294122, make reference to the use of photopolymer as the material in which graded refractive index features are induced by exposure to appropriate light or other radiation, other materials in which refractive index variations can similarly be induced by such exposure, may be used utilising the same exposure techniques. Thus, for example, dichromated gelatine (DCG) may be used as the material in which graded refractive index lenses or other graded

refractive index features are induced to impart light diffusing characteristics to the device.

It is preferable, particularly where the devices are to be used in conjunction with LCD displays, that the device in accordance with the invention or the several layers thereof, should be non-birefringent, i.e. should be polarisation-maintaining.

A particular use of a material in accordance with the invention is as an overlay for front-lit LCD displays in, for example, portable telephones, portable computers etc., to allow the user to view the display from the optimum angle without obstructing incident light and without being troubled by extraneous surface reflections. In such an application of course, no reflective coating is utilised and the or each layer of the diffusing screen should be light-transmitting. In an arrangement such as illustrated in Figure 2, the substrate may be constituted by the, for example glass, cover plate of the LCD display.

Of equal significance are devices in accordance with the invention in which, as in Figures 1a and 1b above, one surface, usually the surface in which the Fresnel structure is present, is coated with a reflecting or partially reflecting coating, typically a metal such as aluminium. Devices of this type may be incorporated behind the liquid crystal cell in a display illuminated using ambient lighting.

In the arrangements of Figures 1a and 1b, light is diffused to a minimum extent on arrival at 35 to 40 degrees to the normal to the lower surface (i.e. the normal to the general "plane" of the material) but is diffused more strongly after reflection at the reflective coating, during the return passage through the diffusing material. These differences in diffusion and intensity are clearly

shown in Fig. 4 where intensity and angle or view resulting from different light entry angles are compared. Thus, Figure 4 shows the characteristics of a planar sheet of graded refractive index light diffusing material. Graph A was derived by directing a beam of light through such sheet of material, arranged perpendicular to the beam axis and measuring the intensity of light (plotted along the Y-axis) emerging from the sheet on the opposite side thereof, along directions at various angles (plotted along the X axis) from the beam axis. Graph B was produced in the same way but with the sheet of graded refractive index diffusing material arranged with the normal to its plane angled at 35° with respect to the beam axis.

In a few applications, it may actually be desirable to reverse the normal light paths obtaining in the sense that it may be desired to have light from the display concerned exit with a maximum intensity along an axis which is inclined significantly to the normal to the plane of the display (and hence to the plane of the overlay sheet) with the incident light entering the display normally or inclined oppositely to the axis along which the emerging light is most intense. Use of the display in this way is herein, for convenience, referred to as use "in the reverse mode".

Whilst, in some of the embodiments described above, the graded refractive index features responsible for the diffusion of light are formed integrally with the material affording the stepped or faceted surface, in other embodiments within the scope of the invention the device is formed as a plurality (e.g. two, three or more) of distinct, superimposed layers, with one such layer, preferably an outer layer, being of a transparent material of uniform refractive index but provided with the ramped or faceted refractive surface and another such layer, for example juxtaposed with the layer with the faceted surface, incorporating the graded refractive index features.

Indeed, in some embodiments where no, or minimal diffusion of light is required, a diffusing layer or surface may be omitted, the overlay or underlay in such a case comprising a simple Fresnel prism plate or reflector or semi-reflector, which may, for example, still be of utility in LCD displays, for example in some applications, in again allowing the user to view the display from the optimum angle without obstructing incident light. However, even where no significant optical diffusion is desired, it is preferred that the "flat" surface of such a plate or sheet, i.e. the surface opposite that provided with the stepped profile, should be sufficiently textured or irregular to minimise reflection of light thereby, (see below).

It has been found that in some applications, particularly in relation to LCD displays, surface reflection, for example from the planar surface generally presented towards the viewer, of a transparent or light-transmitting cover plate through which an image is intended to be viewed, can be troublesome. (This is particularly so for a display used in the reverse mode, as herein defined). The applicants have established that such troublesome reflections can be eliminated, or much reduced, without significantly impairing the functionality of such a cover plate, by a relatively minor texturing or surface relief patterning of the plate surface presented to the viewer, for example by forming such surface with a myriad of minute rounded bumps or hollows which may be, but need not be, in the form of low power lenslets or microlenses for example having diameters of the order of 5 to 10 μ and radii of surface curvature of $< 20\mu$. Preferably, in order to avoid diffraction effects, such microlenses are arranged substantially randomly on the surface of such cover plate. In the preferred embodiment, however, the minute bumps or hollows referred to are of substantially random shape or contour as viewed perpendicular to the relevant surface, although preferably without sharp edges or angles, but with a mean transverse dimension

of the same order (e.g. 10μ). Such surface texturing may be produced, for example, by embossing with plates derived by photo-resist and etching techniques from optical masks bearing a speckle pattern and produced as described in WO94/29768.

It may, indeed, be advantageous to provide such small scale texturing or surface relief on any surfaces in a display assembly which might otherwise produce troublesome reflections.

In a preferred arrangement in accordance with the invention, as illustrated in Figure 5, a light-transmitting plate 90 forming the top or outer plate of an LCD display stack (not shown) has a Fresnel stepped, faceted lower surface 97 and an upper surface 94 which is planar, from a macroscopic viewpoint, but which, on a microscopic scale is characterised by surface relief patterning or texturing taking the form of a plurality of shallow convex bumps 96 arranged at random on the surface. It will be understood that such a plate may also be used elsewhere in an LCD display, for example between the liquid crystal cell and a back-lighting arrangement, with the stepped or ramped surface 92 having a semi-reflective or transfective coating, as described in relation to Figures 1a and 1b for example. It will be understood that Figure 5, like the other figures, is, in effect a much magnified view of the material. It will also be understood that Figure 5 is not intended to represent accurately the relative scales of the bumps or domes 96 and the steps or ramps in the stepped surface 92. By way of example, the sheet 90 may be 50μ or less in thickness and the pitch between corrugations of the Fresnel structure may be 50μ to 25μ . The major surfaces of the ramps or steps may be inclined at 10° to 30° to the overall plane of the sheet material. The sheet or plate 90 may be characterised by graded refractive index variations in the same way as described in relation to Figures 1 to 4, to provide the material with a bulk light-diffusing effect, or may be of uniform

refractive index throughout, with only a very minor light-diffusing effect being imparted by the surface relief 96.

It is not essential that the facets of the ramped, Fresnel structure be optically smooth or perfectly flat. Indeed, in some instances some small-scale roughness or irregularity of the major surfaces of the ramps may be beneficial in contributing to desired diffusion and/or in minimising unwanted specular reflections (e.g. where the structure is principally required to have a refractive effect). Furthermore, a slight convex or concave curvature may be imparted to the ramp surfaces to produce particular desired optical effects.

The present invention, in another of its aspects, provides an optical device which is suitable for use in relation to an LCD display, for example to allow the user to view the display from the optimum angle without obstructing incident light and at the same time to allow light from a back-lighting arrangement to more effectively reinforce reflected incident light.

Referring to the schematic diagram of Figure 6, this shows an LCD display having an LCD cell 100 superimposed upon a plate 102 of light-transmitting material having a planar upper face parallel with the upper and lower plates of the LCD cell and having a Fresnel-stepped or ramped lower surface which is provided with a semi-reflective or transfective coating, 104, the plate 102 being interposed between the LCD cell 100 and a back lighting assembly 106, arranged to direct light towards the cell perpendicularly to the faces of the latter. It will be observed, however, that the light from assembly 106 is refracted by the inclined steps or ramps in the lower surface of plate 102 so that the viewing angle at which the viewer receives light most brightly from the back-lighting arrangement is slightly displaced from the normal, (i.e. from the perpendicular to the display) at which the display is best viewed. Furthermore,

given that the stepped semi-reflective surface is intended to reflect incident light so that it passes normally (i.e. perpendicularly) through the cell 100, one result is that where back-lighting by assembly 106 is being used to supplement reflected illumination the viewing angles for peak back-lighting brightness and for peak reflected ambient light brightness do not coincide so that the reinforcement of reflected light by back light is less than theoretically would be possible. In order to overcome this difficulty, the applicants propose an arrangement illustrated in Figure 7, in which a partially light-reflecting, partially light-transmitting plate comprises, in addition to a first body 110 of light-transmitting material having an upper, outer surface which is generally planar and an inner stepped or ramped surface 114 carrying or juxtaposed with a semi-reflective coating 116, a second body 120 of light-transmitting material is provided on the opposite side of said semi-reflective coating 116 from the first body 110 of material, the inner or upper surface of this body 120 of light-transmitting material conforming to (and, for example, being adhered to) the underside of the coating 116. As the coating 116 (which is naturally of negligible thickness) conforms closely to the ramped surface 114, the lower side of the coating 116 is similarly ramped, as is the upper surface or boundary of body 120 which conforms to its coating 116. The second body 120 of light-transmitting material has an outer, lower, surface remote from the coating 116 which is planar and parallel with surface 112. The refractive index of the second body 120 of light-transmitting material is equal or close to that of the first body 110 of light-transmitting material, in embodiments in which each body 110, 120 is of uniform refractive index throughout, whereby light suffers little or no refraction in passing from said first to said second body of light-transmitting material.

Where, as may be the case in some embodiments, one or other, (or both), of the bodies 110, 120, is characterised by small scale refractive index variations,

imparting light-diffusing properties to the body, the mean refractive index of body 110 is preferably substantially equal to that of body 120.

With a "sandwich" structure of the kind described above with reference to Figure 7, any refractive deviation imparted to a light ray, passing through the structure, at the surface 114, will be reversed at the opposing surface of the layer 120 (infinitesimally close to, or coincident with surface 114) so that for practical purposes the ray will pass through the structure without net deviation. Accordingly when the structure of Figure 7 is used in an LCD display arrangement such as illustrated in Figure 6, in place of the plate 102 illustrated in Figure 6, the light from assembly 106 can pass perpendicularly through the structure and through the LCD cell. Since ambient light entering the structure from above can also be arranged to be reflected back, by the semi-reflective ramped coating 116 normal to the LCD cell, it can readily be arranged that the light from the back-lighting assembly 106 and that reflected at the ramped surface have peak intensities along the same axis relative to the display, and thus reinforce one another most efficiently.

The structure of Figure 7 may be produced in any of a number of ways. For example one of the light-transmitting bodies 110, 120 may be formed by applying a curable transparent liquid plastics resin or lacquer in a layer upon a stepped or ramped mould surface (which may, for example, itself be formed, e.g. by embossing, on a flexible plastics sheet incompatible with said lacquer), so that the surface of the lacquer layer remote from the stepped surface is planar, causing or allowing the lacquer to cure, stripping the cured lacquer, (having now the physical configuration of a plate with one planar and one stepped surface) from the mould surface, depositing a semi-reflective coating, (e.g. a thin, vapour-deposited aluminium coating), on the stepped lacquered surface, thereafter applying a second layer of the same liquid lacquer to the

aluminised ramped surface so that the surface of the second layer remote from the ramped surface is planar and parallel to the planar surface of the first layer, and allowing or causing said second layer to cure.

The arrangement of Figure 7 has an additional advantage, namely that the resulting structure has two opposite parallel faces, which facilitates incorporation of the structure in a stack with other elements having opposite parallel faces, such as LCD cells, polarising sheets etc., and also makes handling of the material during manufacture of such products easier and less exacting.

Indeed, in view of the last-mentioned advantages, a similar arrangement may be adopted where the Fresnel structure is intended to have a refractive, rather than a reflective effect. Such an arrangement may, in effect, correspond with that of Figure 7 but with the omission of the semi-reflective coating 116 (so that the bodies 110 and 120 are directly juxtaposed) and with the refractive indices of the two bodies 110 and 120 being significantly different.

Whilst the arrangement described with reference to Figure 7 has the advantages that light transmitted through the plate is transmitted undeviated, in some applications it may be advantageous for transmitted light to be subject to a predetermined deviation as well as for reflected light to be deviated by reflection, and in such a case, accordingly, the two materials on either side of the semi-reflective coating may be of significantly different refractive indices.

Indeed, depending upon the angles of reflection, etc. involved, it may be useful, in some instances, to rely entirely upon refractive index difference between the two materials to produce a desired degree of partial reflection (or total reflection where the angle of incidence of the light concerned is great enough

for total internal reflection at the stepped interface between the two materials of different refractive index).

In the above description, various references are made to liquid crystal displays or LCDs. It will be appreciated, of course, that the invention is similarly applicable to displays using light valve techniques employing optically active materials other than liquid crystals.

In the present specification "comprises" means "includes or consists of" and "comprising" means "including or consisting of".

The features disclosed in the foregoing description, or the following claims, or the accompanying drawings, expressed in their specific forms or in terms of a means for performing the disclosed function, or a method or process for attaining the disclosed result, as appropriate, may, separately, or in any combination of such features, be utilised for realising the invention in diverse forms thereof.

CLAIMS

1. A partially light-reflecting, partially light-transmitting plate or sheet comprising a first body of light-transmitting material having an outer surface and an inner stepped or ramped surface carrying or conforming with and/or adhered to a semi-reflective coating and a second body of light-transmitting material, on the opposite side of said semi-reflective coating from said first body of material, said other side of said coating being correspondingly stepped or ramped, said second body of light-transmitting material having an outer surface remote from said coating and an inner surface conforming with and/or adhered to said opposite side of said semi-reflective coating, the refractive index of said second body of light-transmitting material being equal or close to that of said first body of light-transmitting material, whereby light suffers little or no refraction in passing from said first to said second body of light-transmitting material.
2. A plate or sheet according to claim 1 wherein at least one said outer surface of said plate has a surface relief or texturing to eliminate or reduce reflection of light at said surface.
3. A light-transmitting plate or sheet comprising a first body of light-transmitting material having an outer surface and an inner stepped or ramped surface carrying or conforming with and/or adhered to a second body of light-transmitting material, said second body of light-transmitting material having an inner surface conforming with and/or adhered to said stepped or ramped surface of said first body, the refractive index of said second body of light-transmitting material being different from that of said first body of light-

transmitting material, whereby light is refracted in passing from said first to said second body of light-transmitting material.

4. A light-transmitting plate or sheet according to claim 3 wherein said inner stepped or ramped surface of said first body of light-transmitting material has a semi-reflective coating and said second body of light-transmitting material thus has its inner surface conforming with or adhered to said semi-reflective coating.

5. A light-transmitting plate or sheet according to claim 3 wherein said stepped or ramped surface has no reflective or semi-reflective coating but wherein the stepped or ramped interface, corresponding with said surface, between said first and second bodies of light-transmitting material is rendered at least partially light reflective as a result of the refractive index difference between the two materials.

6. A plate or sheet according to any of claims 1 to 5, wherein individual portions or facets surfaces of said stepped or ramped surface have surface relief or texturing.

7. A plate or sheet according to any of claims 1 to 6, wherein individual portions or facets surfaces of said stepped or ramped surface are convexly or concavely curved.

8. A plate or sheet according to any of claims 1 to 7, wherein at least one of said light-transmitting materials is characterised by refractive index variations forming light-deviating features imparting bulk light-diffusing properties to the material.

9. A liquid crystal display incorporating a plate or sheet according to any of claims 1 to 8.
10. An LCD display, incorporating a light-transmitting element having a surface with surface relief or texturing to eliminate or reduce reflections.
11. A display according to claim 10 wherein said surface of said element forms the surface of the display which is closest to the viewer.
12. A display according to claim 10 or claim 11 wherein said element has one surface which is stepped to form a Fresnel refracting arrangement.
13. A display according to claim 10 or claim 11 wherein said element has one surface which is stepped and is rendered at least partially light-reflecting to form a Fresnel reflecting arrangement.
14. A display according to any of claims 10 to 13, wherein individual portions or facets of said stepped or ramped surface are convexly or concavely curved.
15. A display according to any of claims 10 to 14, wherein said light-transmitting material is characterised by refractive index variations forming light-deviating features imparting bulk light-diffusing properties to the material.
16. A plate or sheet of light-transmitting material which sheet has one surface stepped or ramped to act as a Fresnel refractor or reflector and has an opposite surface which has surface relief or texturing to reduce reflection of light from that other surface.

17. A plate or sheet according to claim 16 wherein said stepped or ramped surface has a reflective or semi-reflective coating to render the stepped or ramped surface fully or partially light reflective.

18. A plate or sheet according to claim 16 or claim 17, wherein individual portions or facets of said stepped or ramped surface are convexly or concavely curved.

19. A plate or sheet according to any of claims 16 to 18, wherein said light-transmitting material is characterised by refractive index variations forming light-deviating features imparting bulk light-diffusing properties to the material.

20. An LCD display incorporating a plate or sheet according to any of claims 16 to 19.

21. An optical device comprising an element of light-transmitting material having a surface thereof configured to form a stepped, Fresnel-type light refracting element, said element incorporating an array of graded refractive index structures adapted to impart light dispersing or diffusing characteristics to said light-transmitting material, or the element having a layer configured to form said stepped surface and an additional layer incorporating such an array of graded refractive index features.

22. An optical device according to claim 21 wherein said graded refractive index features are of a size which is small in relation to the spacing between adjacent steps of the stepped Fresnel-type surface of said element.

23. An optical device according to claim 21 or claim 22 wherein said element has the general form of an extended, generally planar sheet or layer,

and said graded refractive index structures each have a graded refractive index distribution, in a plane parallel with that of said sheet or layer, which is substantially the same in different parallel planes at successive respective positions along an axis extending from one side of said generally planar sheet or layer to the other.

24. An optical device according to claim 23, wherein said graded refractive index structures each have a graded refractive index distribution in such planes, which is substantially the same at all points along an axis perpendicular to the plane of said sheet or layer.

25. An optical device according to claim 20 wherein each said graded refractive index structure is a lens having an axis extending perpendicular to the plane of said planar sheet or layer, the refractive index within said structure being substantially constant along a line parallel with said axis and varying with distance from said axis.

26. An optical device according to any of claims 21 to 25, wherein one surface of said material is coated with light-reflecting material.

27. An optical device according to claim 26 wherein the stepped surface is coated with light-reflecting material.

1/5

Fig.1.

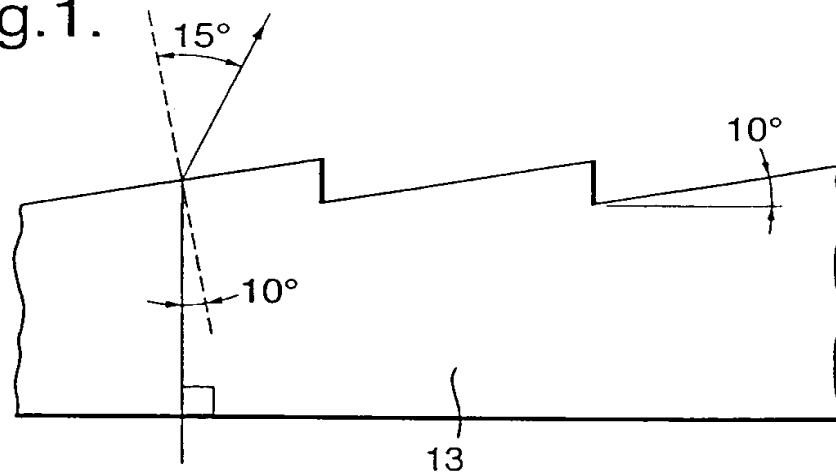


Fig.1a.

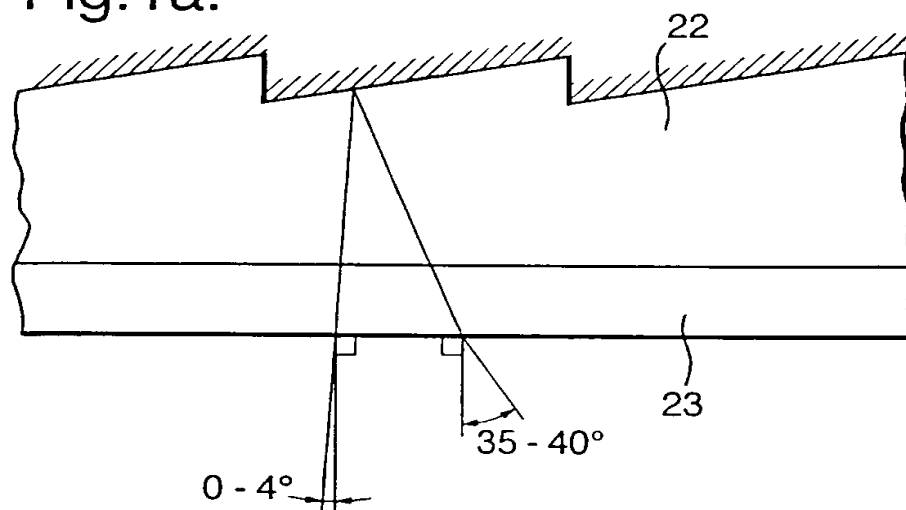
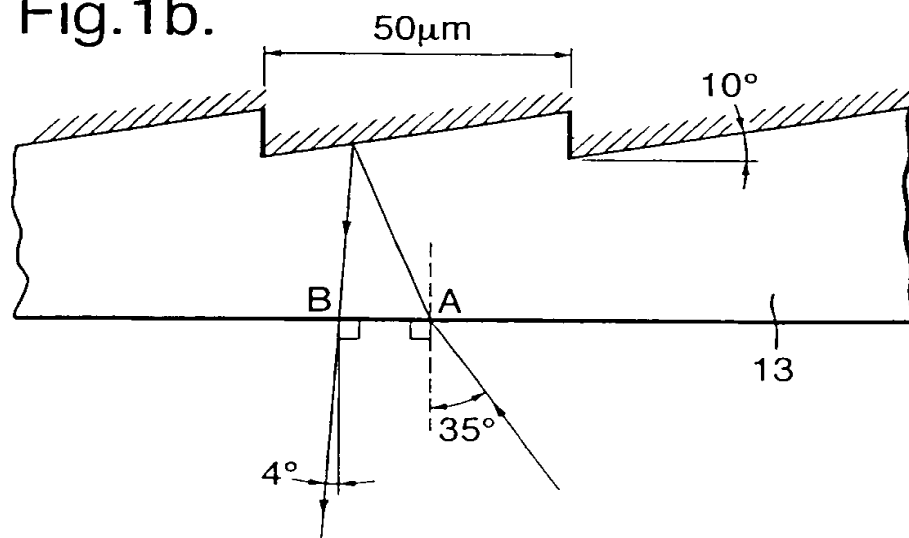


Fig.1b.



2/5

Fig.2.

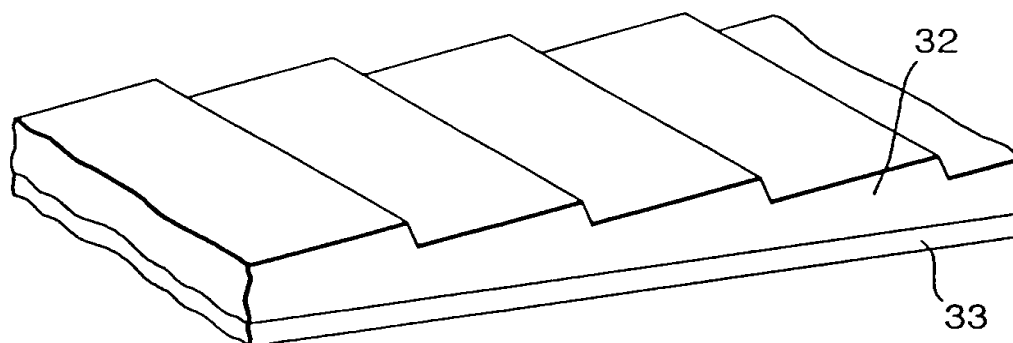


Fig.2a.

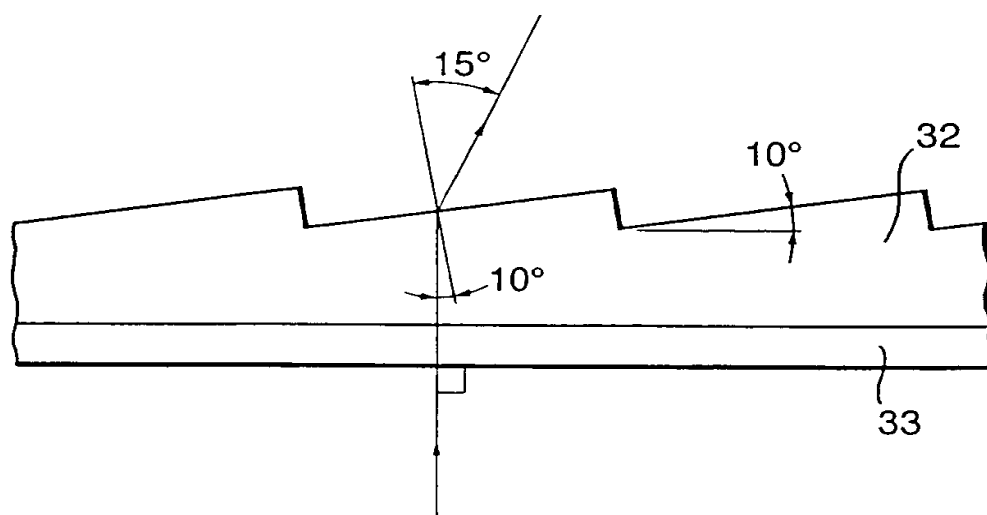


Fig.3.

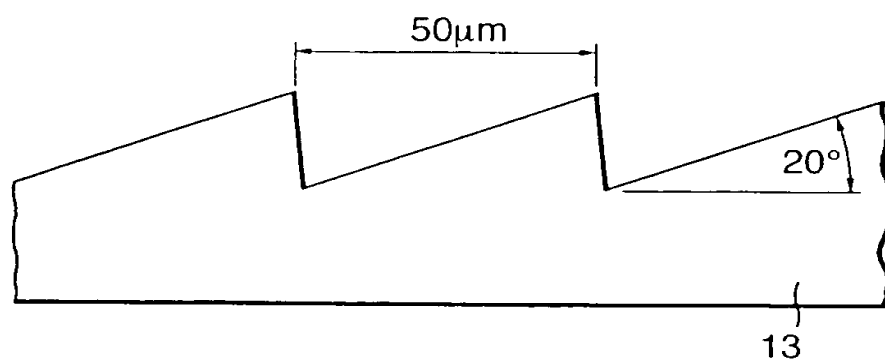


Fig.3a.

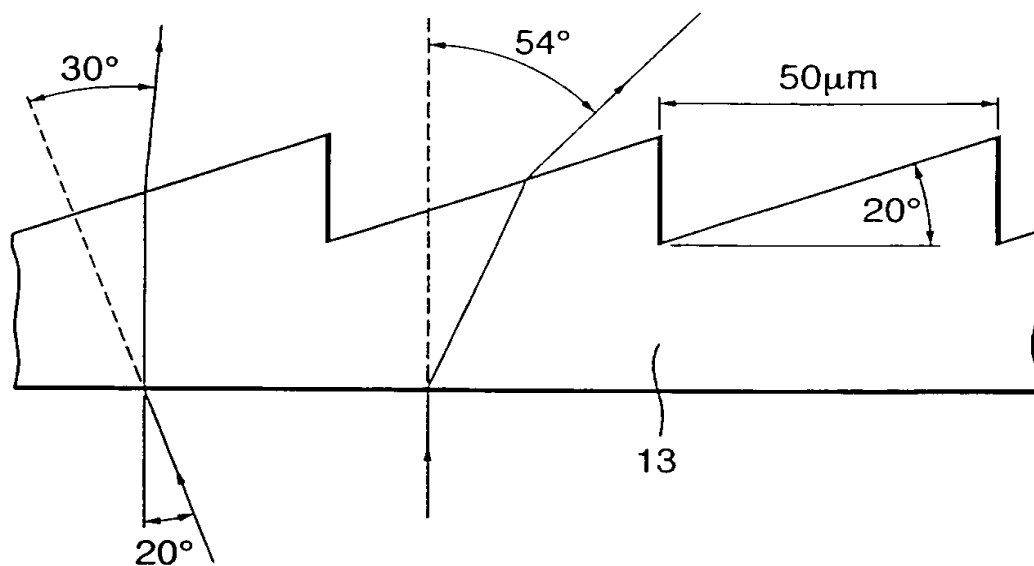
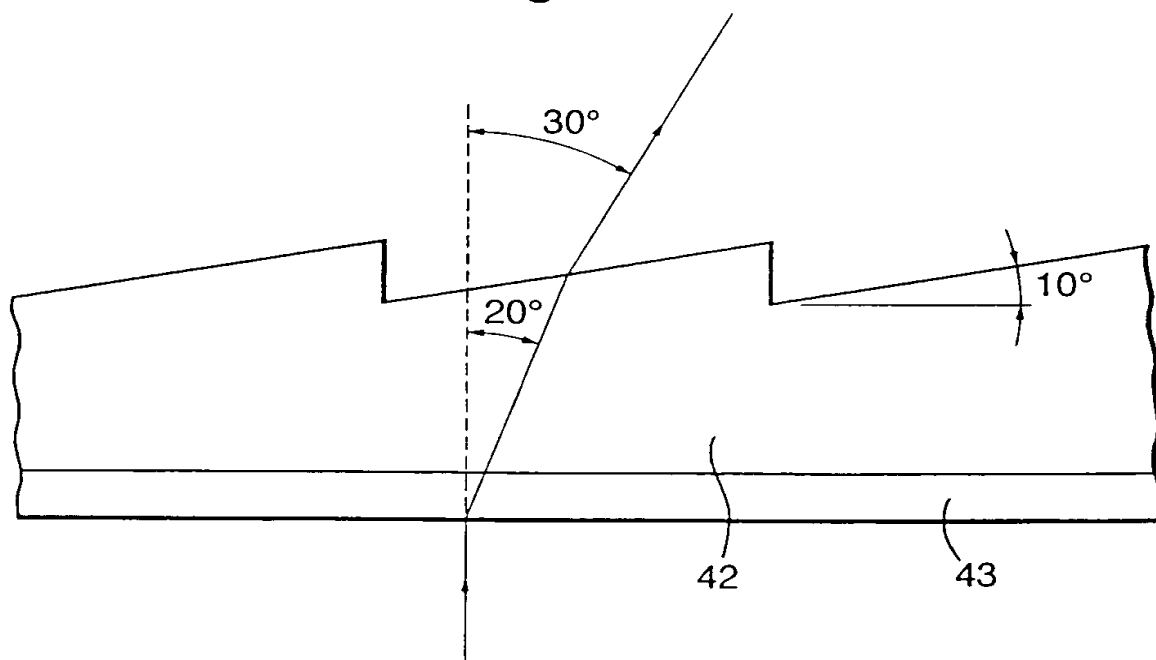
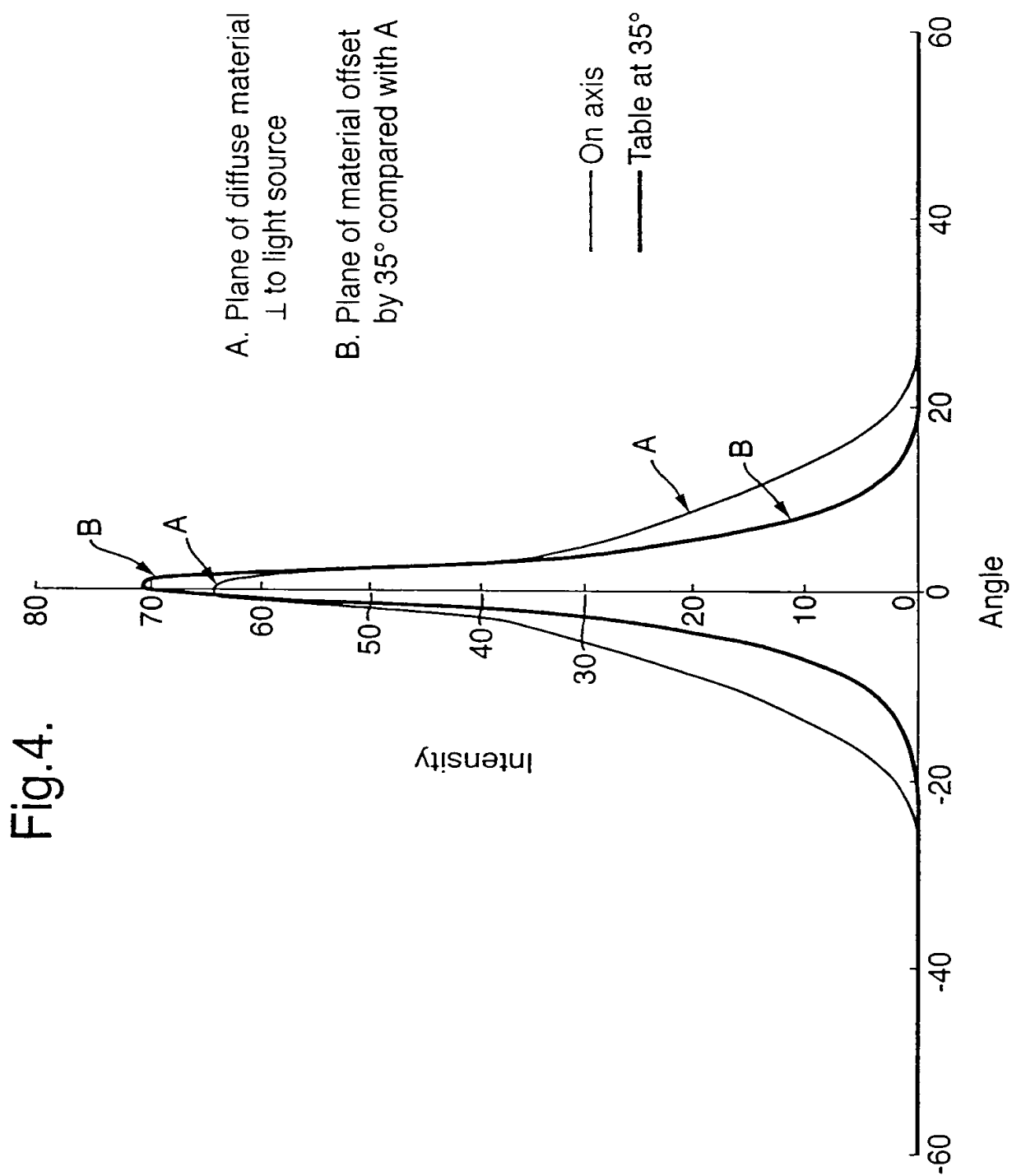


Fig.3b.





5/5

Fig.5.

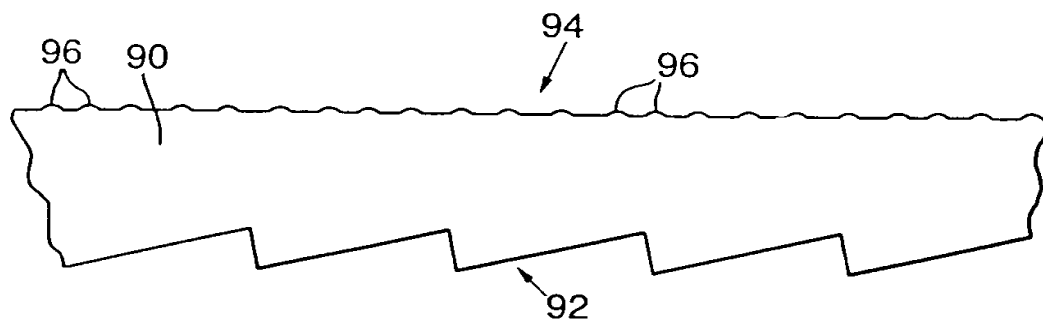


Fig.6.

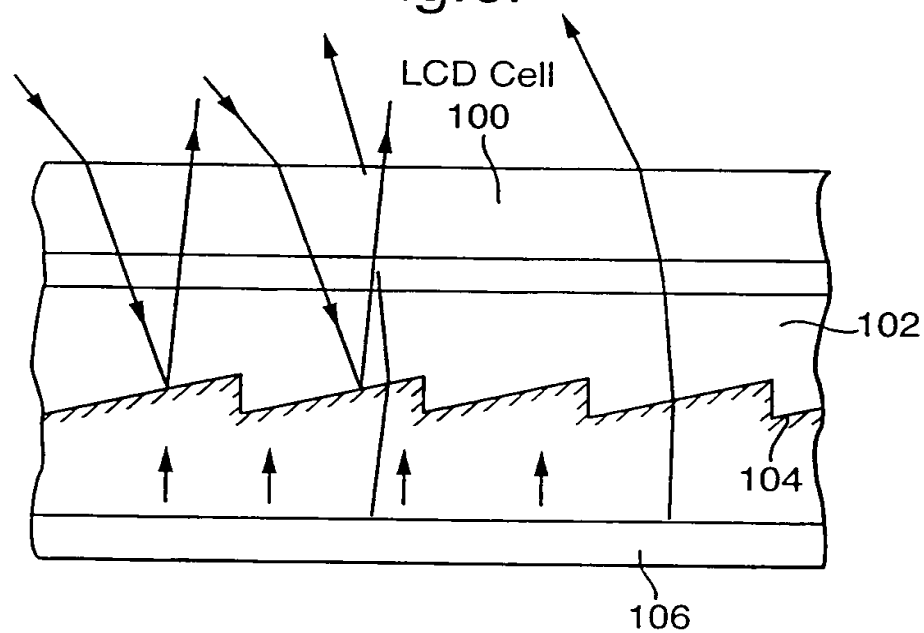
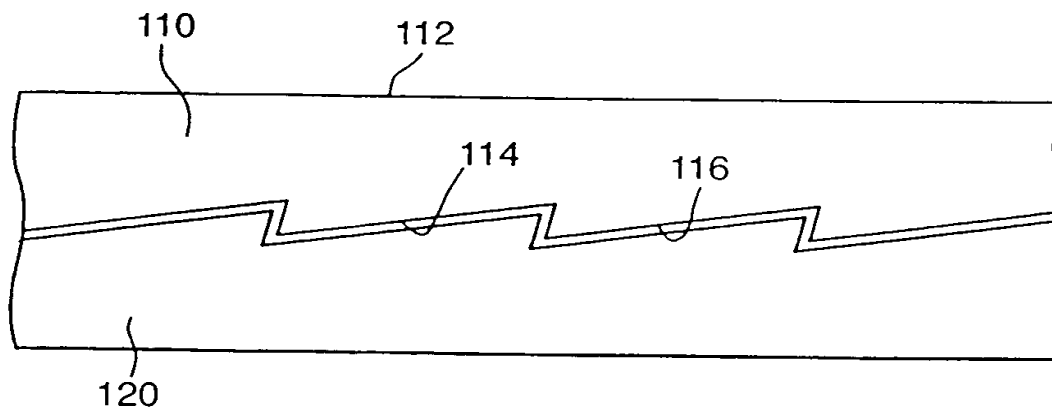


Fig.7.



INTERNATIONAL SEARCH REPORT

Inter Application No

PCT/G0000/01858

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G03B21/62 G02B3/08

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 G03B G02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 573 905 A (MINNESOTA MINING & MFG) 15 December 1993 (1993-12-15) column 4 -column 13; figures 1-6 ----	1,3,4
A	PATENT ABSTRACTS OF JAPAN vol. 006, no. 179 (P-142), 14 September 1982 (1982-09-14) & JP 57 094740 A (MATSUSHITA ELECTRIC IND CO LTD), 12 June 1982 (1982-06-12) abstract ----	1-4
X	US 5 442 482 A (JOHNSON WILLIAM N H ET AL) 15 August 1995 (1995-08-15) column 10 -column 19; figures 1-19 ----	10-25
X	US 5 751 387 A (FUKUHARA MOTOHIKO ET AL) 12 May 1998 (1998-05-12) column 5 -column 9; figures 1-21 -----	16-25

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search

7 August 2000

Date of mailing of the international search report

11/08/2000

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Boeykens, J

INTERNATIONAL SEARCH REPORT

information on patent family members

Inte Application No

PCT/80/01858

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
EP 0573905	A	15-12-1993	JP 6051399 A	25-02-1994
JP 57094740	A	12-06-1982	NONE	
US 5442482	A	15-08-1995	AT 155897 T	15-08-1997
			AU 7881291 A	10-12-1991
			DE 69126975 D	28-08-1997
			DE 69126975 T	27-11-1997
			EP 0530269 A	10-03-1993
			WO 9118304 A	28-11-1991
			JP 5509416 T	22-12-1993
US 5751387	A	12-05-1998	FR 2737595 A	07-02-1997
			FR 2737581 A	07-02-1997